

## WE CLAIM AS OUR INVENTION

1        28) Method of making a silicon penetration device  
2 having an increased fracture toughness, comprising the  
3 steps of:  
4        providing a silicon substrate for the silicon  
5 penetration device, having an initial surface;  
6        heating the silicon substrate to an elevated  
7 temperature;  
8        exposing the heated silicon substrate to a series of  
9 one or more sequential reactive environments, each  
10 containing one or more reactants selected from the group  
11 consisting of oxygen, ozone, steam, hydrogen, ammonia,  
12 nitrous oxide, nitric oxide and nitrogen;  
13        growing an adherent film of a silicon compound on  
14 the initial surface of the silicon substrate during the  
15 exposing step, the adherent film formed by a chemical  
16 reaction between the reactant or reactants and silicon  
17 from the silicon substrate underlying the growing  
18 adherent film;  
19        cooling the silicon substrate with the adherent  
20 film; and  
21        removing at least a part of the adherent film from  
22 the underlying silicon to uncover a new surface on the  
23 silicon substrate;  
24        to provide the silicon penetration device having  
25 increased fracture toughness.

1        29) The method of Claim 28, wherein the new  
2 substrate surface is smoother than the initial substrate  
3 surface for providing the increased fracture toughness of  
4 the silicon penetration device.

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1        30) The method of Claim 28, further comprising,  
2 before the growing step, the additional step of cleaning  
3 the surface of the silicon substrate to receive the  
4 adherent film.

1        31) The method of Claim 30, wherein during the  
2 cleaning step, the surface of the silicon substrate is  
3 RCA cleaned.

1        32) The method of Claim 28, wherein during the  
2 heating step, the heating is accomplished by a furnace.

1        33) The method of Claim 28, wherein during the  
2 heating step, the temperature is elevated to about 1,100  
3 degrees Celsius.

1        34) The method of Claim 28, wherein during the  
2 exposing step, the heated silicon substrate is  
3 simultaneously exposed to multiple selected reactants.

1        35) The method of Claim 28, wherein during the  
2 exposing step, the heated silicon substrate is serially  
3 exposed to multiple selected reactants.

1        36) The method of Claim 28, wherein the growing step  
2 is terminated when the adherent film has grown to a  
3 thickness of about one micrometer.

1        37) The method of Claim 28, wherein during the  
2 removing step, the adherent film removal is accomplished  
3 by an etchant.

1        38) The method of Claim 37, wherein the etchant is a  
2 solution of hydrofluoric acid in water.

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1        39) The method of Claim 28, wherein during the  
2 removing step, the adherent film removal is accomplished  
3 by etching with a buffered oxide etchant.

1        40) The method of Claim 28, wherein during the  
2 removing step, the adherent film is completely removed to  
3 uncover a new surface on the silicon substrate.

1        41) The method of Claim 28, wherein the adherent  
2 film is a silicon oxide compound.

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1        42) Method of making a silicon penetration device  
2 having an increased fracture toughness, comprising the  
3 steps of:  
4        providing a silicon substrate for the silicon  
5 penetration device, having an initial surface;  
6        heating the silicon substrate to an elevated  
7 temperature;  
8        exposing the heated silicon substrate to a series of  
9 one or more reactive environments containing the reactant  
10 or reactants oxygen, steam, or a mixture thereof;  
11        growing an adherent film of a silicon oxide compound  
12 on the initial surface of the silicon substrate during  
13 the exposing step, the adherent film formed by a reaction  
14 between the reactant or reactants and silicon from the  
15 silicon substrate underlying the growing adherent film;  
16        cooling the silicon substrate with the adherent  
17 film; and  
18        etching away at least a part of the adherent film  
19 from the underlying silicon to uncover a new surface on  
20 the silicon substrate;  
21        to provide the silicon penetration device having  
22 increased fracture toughness.

1        43) The method of Claim 42, wherein the exposing  
2 step further comprises the steps of:  
3        exposing the heated silicon substrate to a reactive  
4 environment containing dry oxygen reactant;  
5        exposing the exposed silicon substrate to wet steam  
6 reactant; and  
7        exposing the exposed silicon substrate to dry oxygen  
8 reactant.

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1        44) The method of Claim 42, further comprising,  
2 before the growing step, the additional step of cleaning  
3 the surface of the silicon substrate to receive the  
4 adherent film.

1        45) The method of Claim 42, wherein during the  
2 exposing step, the silicon substrate is exposed to dry  
3 oxygen for about five minutes.

1        46) The method of Claim 42, wherein during growing  
2 step, the reactive environment supports an adherent film  
3 growth rate of about forty Angstroms per minute.

1        47) The method of Claim 42, wherein the growing step  
2 is terminated when the adherent film has grown to a  
3 thickness of about one micrometer.

1        48) The method of Claim 42, wherein during the  
2 etching step, the adherent film is completely etched away  
3 to uncover a new surface on the silicon substrate.

1        49) A penetration device with increased fracture  
2 toughness, comprising:  
3        a silicon substrate which has an initial surface;  
4 and  
5        an adherent film of a silicon compound formed on the  
6 initial surface of the substrate by silicon from the  
7 substrate in chemical reaction with one or more reactants  
8 selected from the group oxygen, ozone, steam, hydrogen,  
9 ammonia, nitrous oxide, nitric oxide, and nitrogen,  
10 which adherent film is at least partially removed to  
11 uncover a new surface on the silicon substrate to provide  
12 the increased fracture toughness of the silicon  
13 penetration device.

1        50) The device of Claim 49, wherein the adherent  
2 film is completely removed to uncover a new surface on  
3 the silicon substrate.